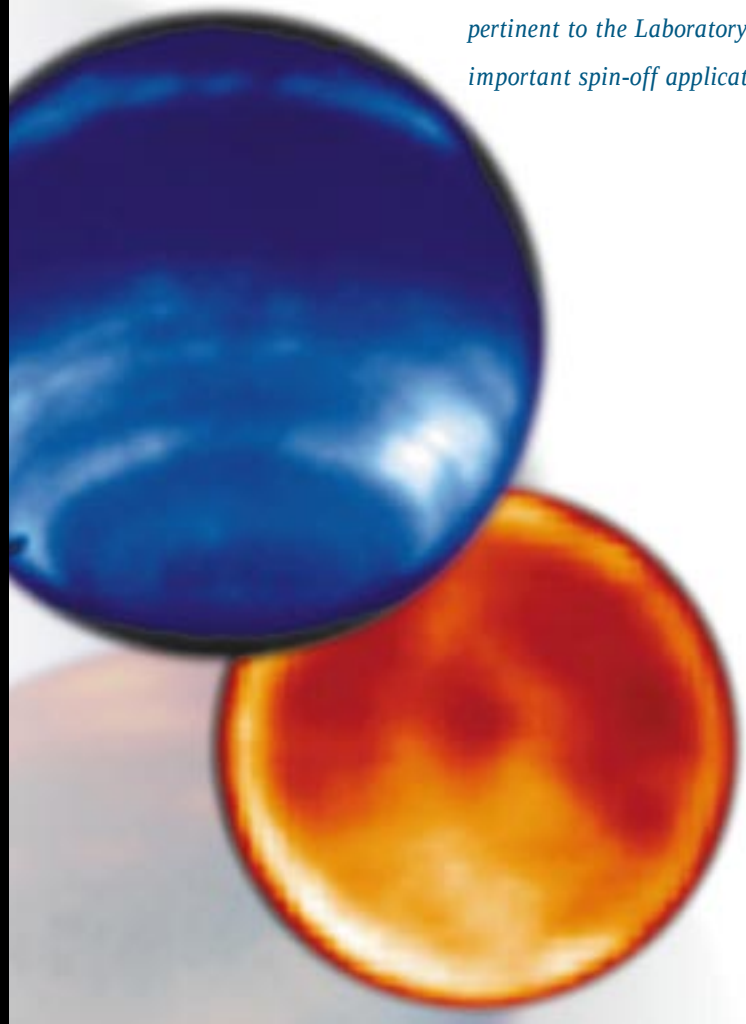
Breakthroughs in Science and Technology

The pursuit of fundamental science and the advance of applied technology go hand in hand at Livermore. State-of-the-art technology is used to increase our understanding of science in areas pertinent to the Laboratory's major missions. Conversely, Livermore's scientific advances have important spin-off applications and help to achieve program goals.



In an image taken with the Keck II telescope, a prominent storm system can be seen on the lower right of Neptune's disk, and haze is present over the north polar regions (top). Titan (bottom), Saturn's largest moon, exhibits dark surface features in the northern hemisphere that may be lakes or seas of liquid hydrocarbons.

Best-Ever Images of Neptune and Titan

In 1999, the best-ever Earth-based images of Neptune and Titan, Saturn's largest moon, were taken by a Livermore-led team of scientists using the W. M. Keck II telescope in Hawaii. Keck's infrared detectors penetrated into the deep layers of Neptune's roiling atmosphere. The images show giant Neptunian storms driven by prevailing winds of 600 miles per hour. The pictures of Titan reveal features that could be frozen landmasses separated by hydrocarbon seas and lakes. These images will help researchers determine beforehand where to land the Huygens probe from the Cassini spacecraft, which is expected in 2004.

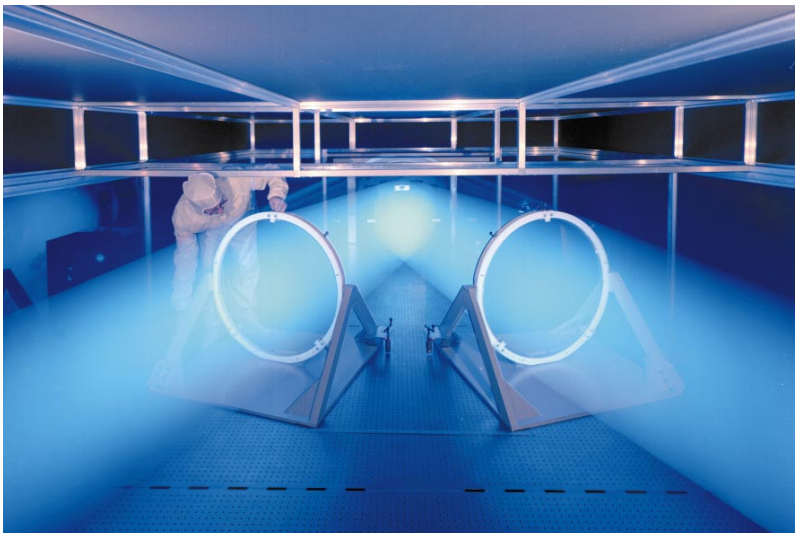
The images were taken with the newly installed adaptive optics system, which Livermore researchers helped to develop and install. In adaptive optics, mirror adjustments are used to remove Earth's atmospheric turbulence from the telescope's images, producing unprecedented clarity.

Ultrashort-Pulse Lasers Generate Antimatter

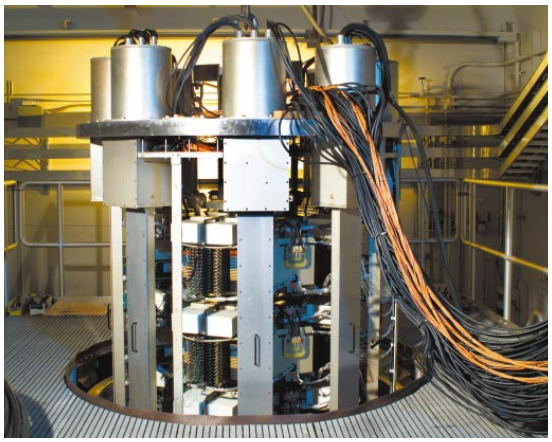
Laboratory researchers and their collaborators used the world's most intense and powerful laser to generate a short-lived fireball of energy that produced antimatter and stimulated nuclear fission. These exciting results were reported to the centennial meeting of the American Physical Society in March 1999.

The work opens the door to the world of photonuclear physics. Research that once was the province of huge particle accelerators can now be approached through high-energy laser–matter interactions. Building on Livermore's groundbreaking work, future researchers may be able to create nearly instantaneous, detailed images of nuclear and atomic structures—and possibly even proteins. They may also be able to create and study matter–antimatter plasmas like those near neutron stars and black holes.

The experiments were performed using Livermore's Petawatt laser, which ceased operation with the shutdown of Nova in July 1999. The laser's



Livermore has unique capabilities to fabricate large diffraction gratings, which we use to stretch and later recompress petawatt-level laser pulses by a factor of 25,000 so that optical components are not damaged.



One of our 1999 R&D 100 Award winners is a much-improved power modulator for advanced accelerators, the first one based on solid-state components. Developed to improve radiography for stockpile stewardship applications, the modulator technology also helps to make feasible the Next Linear Collider, a next-generation high-energy particle accelerator.

petawatt of power—a million billion watts, or more than 1,200 times the entire electrical generating capacity of the U.S.—was produced in pulses less than a trillionth of a second long.

Ultrashort-pulse lasers on a smaller scale are finding breakthrough applications in precision manufacturing and scientific research. For example, using an ultrashort-pulse laser compact enough to fit on a large table, another Livermore-led team of scientists created tiny fusion explosions. The continuing research is aimed at increasing the number of fusion neutrons produced. The highly energetic neutrons can be used as probes, much like x rays, to investigate defects in materials ranging from metals to human tissue.

New "Stable" Super-Heavy Element Created

Researchers from Livermore and the Joint Institute for Nuclear Research in Dubna, Russia, discovered element 114. With 114 protons and 175 neutrons in its nucleus, the super-heavy element existed for 30 seconds before decaying into lighter elements. Element 114 lies in a predicted island of nuclear stability, a long-sought experimental goal, and lived 100,000 times longer than the previous new element found, element 112.

In a 40-day-long experiment that generated just one atom of element 114, the scientists used a heavy-ion cyclotron to bombard a film of plutonium-244 with calcium-48 atoms. Livermore supplied the plutonium-244, which is an exotic isotope that is difficult to manufacture. As part of the collaboration, Laboratory scientists also provided independent data analysis of the results. Since the team's discovery in December 1998, different isotopes of element 114 have been created, and other researchers have produced additional super-heavy elements—116 and 118.

Six R&D 100 Award Winners in 1999

Livermore scientists and engineers earned six R&D 100 Awards for outstanding achievement in research and development. Each year, *R&D Magazine* presents the awards to the top 100 industrial, high-technology inventions submitted to its competition. The Laboratory's award winners (listed on p. 30) will find applications in laser machining, communications, computer-chip manufacturing, cancer therapy, and law enforcement. They bring to 81 the number of R&D 100 Awards won by Livermore researchers.